SOME PECULIARITIES OF THE NOVÆ.

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There are no more interesting objects in the sky than the novæ. The suddenness with which they rise from a faint or obscure condition or even from absolute invisibility, sometimes to outrank all the other stars in the heavens, in some cases increasing their light as much as a hundred thousand fold, is very wonderful. This great rise in brightness requires only a few hours or a few days at most. Their rapid physical changes, the various colors through which they pass in their declining light, their later change to apparently a nebulous state, and their final return to what seems to be their original condition which they attain in a few years' time, make them of the greatest interest from every point of view.

The novæ remain at their greatest brightness for a very brief period, which in some cases can be counted in hours. They then begin to fade, at first rather rapidly, then slowly. With many halts and minor outbursts they finally, in a few years' time, say from eight to ten or fifteen years, return to their original brightness. This interval of decline seems to vary in different novæ. Though they thus follow the same process of rapid change in brightness and physical condition, there are decided differences and peculiarities among them that might suggest great dissimilarity in their pre-nova state.

One fact that is peculiar to them, though not necessarily definite in its character, is that with perhaps one exception (that of Nova Coronæ of 1866) all of the novæ are found in the Milky Way. Of course, there are vastly more stars in the Milky Way than outside of it and therefore a greater chance for a nova to appear in it. There are other evidences, however, that they really belong there.

What was the original condition of a nova? Little is known of the early history of these bodies—before their outburst of light. We

know something of the visual history of Nova Coronæ Borealis of 1866, for it was observed at Bonn, previous to its outburst, as BD + 26° 2765 of the 9.5 magnitude. Though this star appeared some distance from the Milky Way (in which the novæ apparently belong), there is no other reason to question its character as a nova.

There is now some evidence that possibly the novæ were all variable stars in the earlier stages of their history, but the proof is not conclusive. Photography has shown that at least two of these stars were small variables before they became novæ. Nova Persei is the best example. Thanks to the splendid collection of stellar photographs of the Harvard College Observatory extending over more than a third of a century, we know that previous to its sudden appearance in 1901, when it became brighter than the first magnitude, Nova Persei was a small variable star of about 14th magnitude. After its outburst in 1901 it slowly faded to its original brightness and again became a small variable star—varying perhaps just as it did before the blaze-up. Apparently the great outburst was only an interruption in its regular variability, which is now past and forgotten.

The other, Nova Aquilæ of 1918, which became brighter than any star in the sky with the exception of Sirius and perhaps Canopus, previous to June 8 was also a small variable star of 10.5 magnitude. It has not yet sunk to its original faintness, certainly not from a photographic standpoint, though it has nearly done so. It is only by comparing the present photographs of it with the early ones that we can tell when this event occurs. It will probably resume its variability later on. Of course, these statements of variability have nothing to do with the peculiar fluctuations of the light of a nova in its immediate decline from its maximum.

As we have said, it would appear that the outburst in these two stars was only an interruption in their variability. Professor Turner has made an attempt to connect up the present variability of Nova Persei with that before the great change occurred, but he has not yet obtained a satisfactory result.

Perhaps the phenomena of Nova Aquilæ were of even greater interest than those of Nova Persei. This was probably due to the extremely great brilliancy of the star at its maximum. Its entire

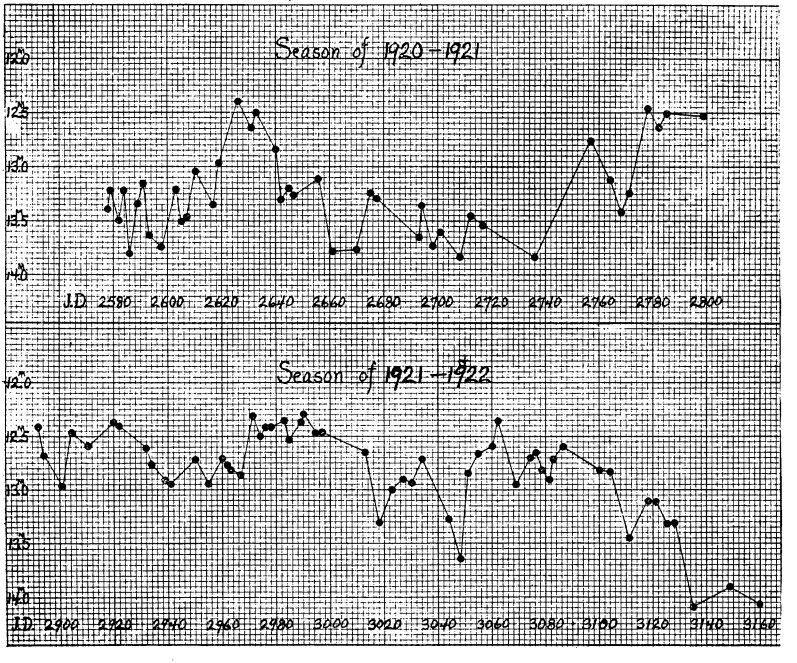
declining phase was brighter than that of any other modern nova, for it was originally a brighter star than any of them with the exception of Nova Coronæ of 1866, whose range of brightness was not nearly so great. Before the outburst Nova Aquilæ was a comparatively bright star of 10.5 magnitude. Nearly all of the other novæ have started either from a very faint condition or from one of entire invisibility. It is easy to show that if some of the other novæ had been as bright as Nova Aquilæ in the beginning they would have much outranked it when at their maximum brightness. This was specially so in the case of Nova Persei, which would have been a brighter star than Nova Aquilæ, because its entire increase of brightness was much the greater of the two. This has given some hope that the great nova of 1572 (Tycho's star), which was by far the brightest nova on record, may have been a considerable star when the outburst occurred, and that it may now be visible as such. But we have no means of identifying it. The uncertainty of Tycho's position of it and the rich region of the Milky Way in which it exists makes it quite impossible to identify it among the many stars in its immediate region. Should, however, a small variable star be found sufficiently near to its assumed place, it would add much to the supposition that the great nova had been found. It would be interesting to recover this star now, for it might be bright enough for spectroscopic study. The great lapse of time since it appeared in 1572 might give results of much value in the history of these stars.

There seems to be good claim that P Cygni of 1600 was a real nova. It is therefore the oldest nova that we can certainly identify. If we follow the information we already have of the novæ, it would seem that this star, if a true nova, was probably visible to the naked eye previous to its outburst.

The next oldest, and one where there is no doubt of identity, is Hind's Nova Ophiuchi of 1848. Though this star was not bright enough to attract very wide attention, a few astronomers observed it carefully. Bond, at the Harvard College Observatory, measured its position with respect to a small star near it. From this it is identified with certainty. While bright enough, it was also observed at Bonn and is BD — 12° 4633. Recent observations show that the star is probably variable.

Nova Cygni of 1876, which was discovered by Schmidt at Athens, attained the second magnitude and was therefore a very bright object to the naked eye. It has long since returned to what was probably its original condition—that of a very faint star of perhaps 15th magnitude. For many years at least it has been irregularly variable with a light range of over one magnitude.

The old novæ that are now variable do not seem to have any definite periods. They are very irregular in their fluctuations and



Light changes of Nova Persei.

in the extent of their light changes. These light changes do not resemble those of the ordinary variable star, for their variability seems to be of a spasmodic nature with no distinct period. It is therefore very important to know if their original variability was of this same erratic nature, so that we can tell if they have entirely resumed their original condition. Photography will play a highly important part in answering this question for some of the future novæ. At present, for Nova Persei and Nova Aquilæ, there is not enough material to tell us what their pre-nova state really was, fur-

ther than that they were variable. The erratic variation of the light of Nova Persei, for two consecutive seasons, is shown in the accompanying diagrams. It will be seen that the extreme variation of the star is about two magnitudes. The two lower sets of figures (J. D.) are the Julian Day; those on the side are magnitude. These are on Seares's scale.

It must be borne in mind, however, that not all the novæ become variable stars on regaining their normal condition. Nova Lacertæ of 1910 (Espin), up to the most recent observations after its return to its original brightness, is perfectly steady in its light, or if there is any fluctuation it is too small to be detected by ordinary means.

One of the first of the novæ to be carefully studied with the spectroscope was Nova Aurigæ of 1891. This star was discovered visually by Anderson in January of 1892. It was later found that the Harvard College Observatory photographs showed it as early as December 10, 1891.* Though it never became very bright, it gave more information of the physical condition of these bodies than any previous nova, mainly from the fact that the spectroscope, then but fairly starting on its wonderful career, aided by photography, was applied to the study of its light. We know nothing of the history of this star before its appearance in 1891.* It has probably long ago returned to its original brightness. There are some suggestions in recent observations of it that it is now also variable.

In its early stage, when in the decline from its maximum, this star showed one remarkable feature that has not been repeated in any other nova. In April of 1892 Mr. Burnham followed it with the 36-inch telescope of the Lick Observatory until it got too near the sun for observation. When he last observed it, on April 26, it had faded to 16th magnitude. Having passed the sun, it was found by Campbell in August of the same year to have risen to 9½ magnitude, and was a conspicuous telescopic object. It had apparently increased its brightness by six or seven magnitudes. In again fading it does not seem to have reached the low magnitude at which Mr. Burnham had seen it in the last of April, 1892. It is now about 14th or 15th

* A photograph taken by Dr. Max Wolf at Heidelberg, Germany, on December 8, 1891, shows nothing in the place of Nova Aurigæ as bright as the eighth magnitude. The star, therefore, must have made its appearance between December 8 and December 10, 1891.

magnitude. As I have stated, no other nova is known to have shown this second bright maximum.

Some of the novæ present very beautiful phenomena, especially in the wonderful colors they sometimes exhibit in their declining phases. At first these stars seem to be white; very soon they become red and pass through various colors, finally ending in a more or less colorless condition, their faintness preventing any appearance of color in them, if it existed. Their most beautiful colors, however, are seen in the telescope, usually after they have ceased to be visible to the naked eye—if they have been so bright as that. I would speak specially of two of these stars of recent years which have shown the most beautiful colors.

In March of 1919 Nova Aquilæ, in the telescope, was the most exquisite and intense blue, a color that no other star in the heavens could match. In September, 1920, Denning's Nova Cygni was a most remarkable object in a large telescope. At the ordinary focus was a white or nearly white stellar image surrounded by a brilliant system of crimson rays. At 9 mm. outside the focus the image was very small and beautifully scarlet. It was surrounded by splendid blue and golden rays. In one position of focus there was no central image, but a system of rays radiating from the center. For the first half of their length these rays were golden, while their outer half was crimson. The crimson color was due to the a Hydrogen line which was then specially strong in the spectrum of the star and gave a beautiful scarlet stellar image 9 mm. outside the normal focus.

The two great novæ of recent years, Nova Persei and Nova Aquilæ, have shown in their declining phase a remarkable phenomenon—that of a measurable planetary disc instead of the stellar point which all stars exhibit. In the case of Nova Aquilæ this measurable disc lasted for at least two months and seemed to be gradually increasing in size. On October 5, 1918, its measured diameter was 0″.8, while on December 14 it was 1″.8. The disc was sharply defined and its light was dull and planetary. Later the star resumed the regular stellar image. Aitken, in August and September of 1919, found, with the 36-inch telescope of the Lick Observatory, that with the telescope set for the focus of the nebulium lines N_1 and N_2, 8 mm. outside the normal focus, there was a definite disc 2″.4 in diameter.

This was verified spectroscopically by Moore and was increasing in size.

In a previous paper (*Monthly Notices of the Royal Astronomical Society,* Vol. 72, p. 673, June, 1912) I have criticized some of the theories concerning the novæ; the encounter with a nebula, the collision theory, etc. In this connection was also criticized the theory that the apparent recession of nebulous matter from Nova Persei was due to the successive illumination of the details of a nebula in which the star was placed, by the outgoing light from the nova. This did not seem satisfactory because it was shown that certain details, such as the "arrow head" in the photographs by Ritchey and Perrine, were in actual motion away from the star and could not be due to light reflection from the nebula. This light reflection theory still seems to hold with some astronomers. There is much question, however, as to its correctness. Recent photographs of Nova Persei have been made by Lampland at the Lowell Observatory, not of the original nebulosities, for they are gone, but of the new nebulosity of 1916, December 16, which, as shown by the photographs by Professor Lampland, is moving out very slowly from the star. This slow motion, if its slowness is not due to motion nearly in the line of sight, seems to have no relation to the rapid movement of the masses in the earlier photographs of 1901, and it certainly can not be identified with any of the details of those pictures. Nor can the present nebulous disc about the star as photographed at Mount Wilson—so like a planetary nebula—be traced on the earlier photographs.

The most satisfactory theory to account for the novæ, especially with respect to Nova Persei, is that the forces of equilibrium of the interior of the star were disturbed, and that there was an outburst in the nature of an explosion, which, though it produced the great brilliancy in 1901, apparently neither destroyed the star nor very seriously affected its variability.

Summary.

The novæ usually appear suddenly in the sky. Their advent is entirely unheralded and it is only in recent years, through photography, that anything has been known of their former existence. The reason for their sudden appearance is unknown. It is probable that

for some cause the forces of equilibrium in the star become unstable and there occurs a great outburst of light in the nature of an explosion. This does not actually destroy the star, for later on, in the course of a few years, it returns to its original brightness and probably to its former physical condition. This is shown by the fact that Nova Persei of 1901 was originally a small variable star. Having now returned to its original brightness, it is again variable.

Sometimes in their decline from maximum these stars present a well-defined, measurable, planetary disc and finally become perfectly stellar again. Always, at one period of their decline, they present a beautiful, sharply defined, crimson image 9 mm. outside the normal focus in such a telescope as the 40-inch refractor of the Yerkes Observatory. This is due to the presence of the a Hydrogen line, which is then strong in their spectra. This always occurs several weeks after their first appearance.

When they first appear they are very white. They soon turn red and in the end become white or colorless again. In their decline they pass through many very beautiful colors, such as an intense blue and gold and crimson—colors that no ordinary star shows in such exquisite purity. This is all due to the nature of their light, through their changing physical condition.

YERKES OBSERVATORY,
WILLIAMS BAY, WISCONSIN,
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